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Coronavirus Aerosol

What is an Aerosol?

Aerosols are small particles that are solid, liquid, or a combination of both, suspended in air. They have broad environmental impacts that include detrimental health effects when inhaled and deposited in the respiratory system. Particles span a large range of sizes, from a few nanometers (nm) to cloud drops of 50 microns (μm) or larger. The smaller particles, so called $PM_{2.5}$ aerosols (diameter less than 2.5 μm) tend to have greater adverse health effects since they can penetrate deep into the lung. Nanoparticles (typically defined as smaller than 0.1 μm), a subset of $PM_{2.5}$, are considered to be especially hazardous since they penetrate deepest into the lung and are small enough to pass through membranes, translocate to various organs and enter cells. Non-engineered particles, such as those produced by 3D printing, are largely in the nanoparticle size range. $PM_{2.5}$ is primarily associated with outdoor air pollution produced from combustion emissions and gas-to-particle conversion processes. In contrast, particles with sizes larger than 2.5 μm, known as coarse particles, are largely produced by mechanical processes, such as wind-blown dust and by coughing or sneezing.

The Coronavirus Aerosol

Recent studies have shown that the coronavirus can exist as an aerosol and be transported in the air. It can also settle on surfaces and be physically transported. Coronavirus infects the respiratory tract, and can be spread by an infected person via coughs, sneezes, or other means that generate liquid aerosol droplets into the air. These drops dry rapidly, decrease in size, and eventually deposit on surfaces due to gravitational settling. Depending on proximity, the virus may come in contact with nearby individuals by air or physical contact. The process is complicated and depends on many factors such as ambient environmental conditions (e.g., relative humidity), variability in particle size, and air flow patterns in the region surrounding the person emitting the aerosols.

Physical transport can occur by touching surfaces contaminated with the coronavirus and then carrying it to the face, eyes, nose or mouth. This raises the issue of how long the virus can live once it is deposited on a surface. A major focus of the current recommendations on how to limit exposures is associated with the idea that the virus may survive from hours to days, depending on the type of surface. Longer duration of survival has been observed on hard surfaces. The recommendations of disinfecting surfaces and minimizing hand-to-face contact are ways to minimize the transport of deposited viruses from surfaces to the upper respiratory system.

Aerosol cloud of droplets formed when sneezing. (WHO report)

Aerosol Transmission Processes

Of particular interest is how and to what levels aerosol droplets containing coronavirus can be generated from an infected person. Any process that expels air from the nose or mouth will make aerosol droplets; coughing (about 3,000 droplets) and sneezing (somewhere on the order of 40,000 droplets) produce the most. Talking for about 5 minutes is considered to produce a similar number of droplets as coughing (see WHO report). Coughing, especially sneezing, expels the droplets out at a high speed forming a droplet cloud. As the surrounding air is less humid, the droplets dry and lose water (the virus remains in the drop), thus becoming smaller. This process is very rapid, typically less than a second.

Another interest is how long the droplets can remain in the air before being inhaled by someone else or eventually getting deposited on surfaces. The main factors that determine how the droplets behave are their aerodynamic properties, which depend on droplet sizes (i.e., diameter). In perfectly still air, the terminal settling speed of a droplet primarily depends on the droplet diameter squared (Hinds). Small particles fall very slowly while large particles (or droplets) fall out quickly. This can be seen in Figure 1, which shows the time a droplet will remain airborne if falling in still air from a height of 6 feet. A common estimated size of

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expelled droplets that have dried is about 5 μm in diameter, (with a range of 0.5 to 12 μm). Based on Figure 1, that corresponds to a lifetime in still air of about 40 minutes, (with a possible range of about 2 days to 10 minutes). This is an idealized situation or could be considered a best-case scenario for deposition.

Turbulence in the surrounding air or the behavior of emitted droplets in one sneeze as a cloud could substantially increase the lifetime of the aerosols. Upward air currents and cloud behavior can counteract settling, keeping the drops in the air for a longer time (MIT press release). The longer they are aloft, the further distance they can spread, which leads to a greater chance of someone coming into contact with the aerosols. Offsetting this is air dilution. The actual concentrations of the virus-containing drops will decrease rapidly in distance from the person expelling them. This means that the deposition pattern to surfaces will be the greatest near the person, as will chances of exposure by inhaling any airborne drops. Thus, very small droplets that can remain airborne for long times would be highly dispersed, offsetting concerns over exposures.

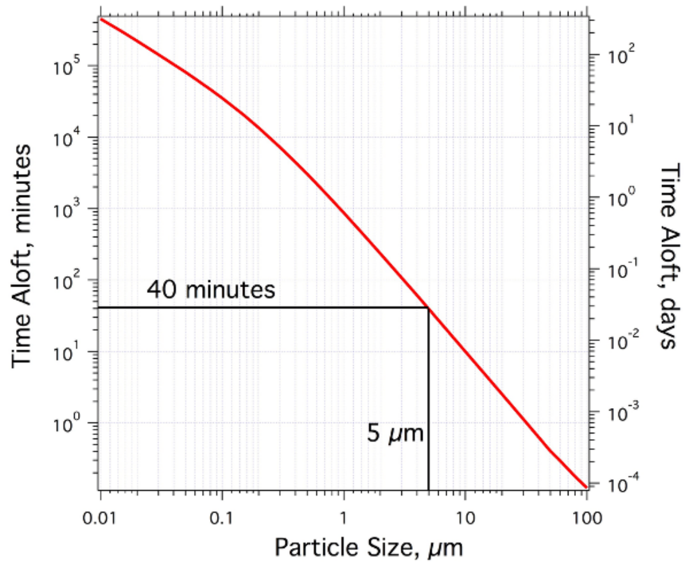

Figure 1. Estimate of time a virus-containing droplet remains in the air if expelled into still air at a height of 6 feet (i.e., the time to fall 6 feet).

Bottom Line

These various transmission opportunities support the importance of (and reasons for) recommendations on limiting hand-to-face (including eyes, nose and mouth) contact, disinfecting surfaces thoroughly and maintaining physical space between individuals through social distancing.

References

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Articles of Interest

https://preventdisease.com/news/14/040914_MIT-Show-Coughs-Sneezes-Travel-200-Times-Further-Than-Previously-Thought.shtml?no_redirect=true

https://www.nytimes.com/2020/03/17/health/coronavirus-surfaces-aerosols.html?action=click&module=Top%20Stories&pgtype=Homepage

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